Opportunities for CEEs to Contribute to Climate Change Mitigation and Adaptation

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Lecture Outline

- ***A few key definitions and basics***
- Climate change as an historic environmental and societal disruptor
- CEE contributions to climate change mitigation
- CEE contributions to climate change adaptation and resilience
- Our professional and leadership responsibilities as CEEs in abating the climate change crisis

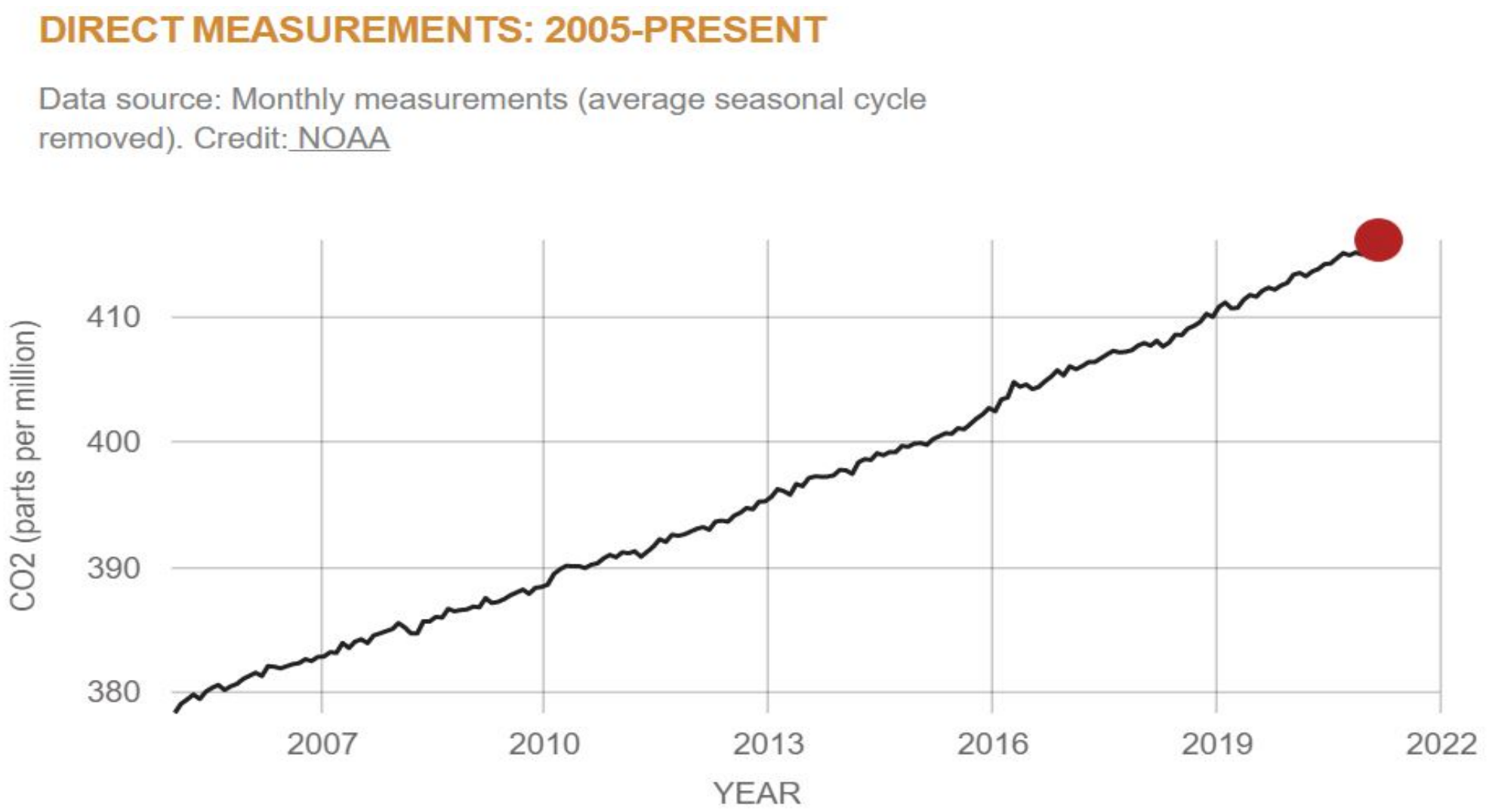
Key Definitions (in Context of Current Climate Change Crisis)

- **Climate Change**
  - A change in global or regional climate patterns attributable to increased levels of atmospheric greenhouse gases (GHGs, such as carbon dioxide and methane).
- **Mitigation**
  - An action by humans to reduce GHG emissions or to capture those emissions and prevent them from entering the atmosphere (e.g., replacing energy from fossil fuels with renewable energy).
- **Adaptation**
  - An adjustment to natural or human systems in response to the actual or expected harmful effects of climate changes (e.g., building flood barriers to protect coastal cities).
- **Resilience**
  - The capacity of infrastructure and communities to anticipate, prepare for, and respond to climate-induced stressors (e.g., developing a reliable water supply for extended drought scenarios).

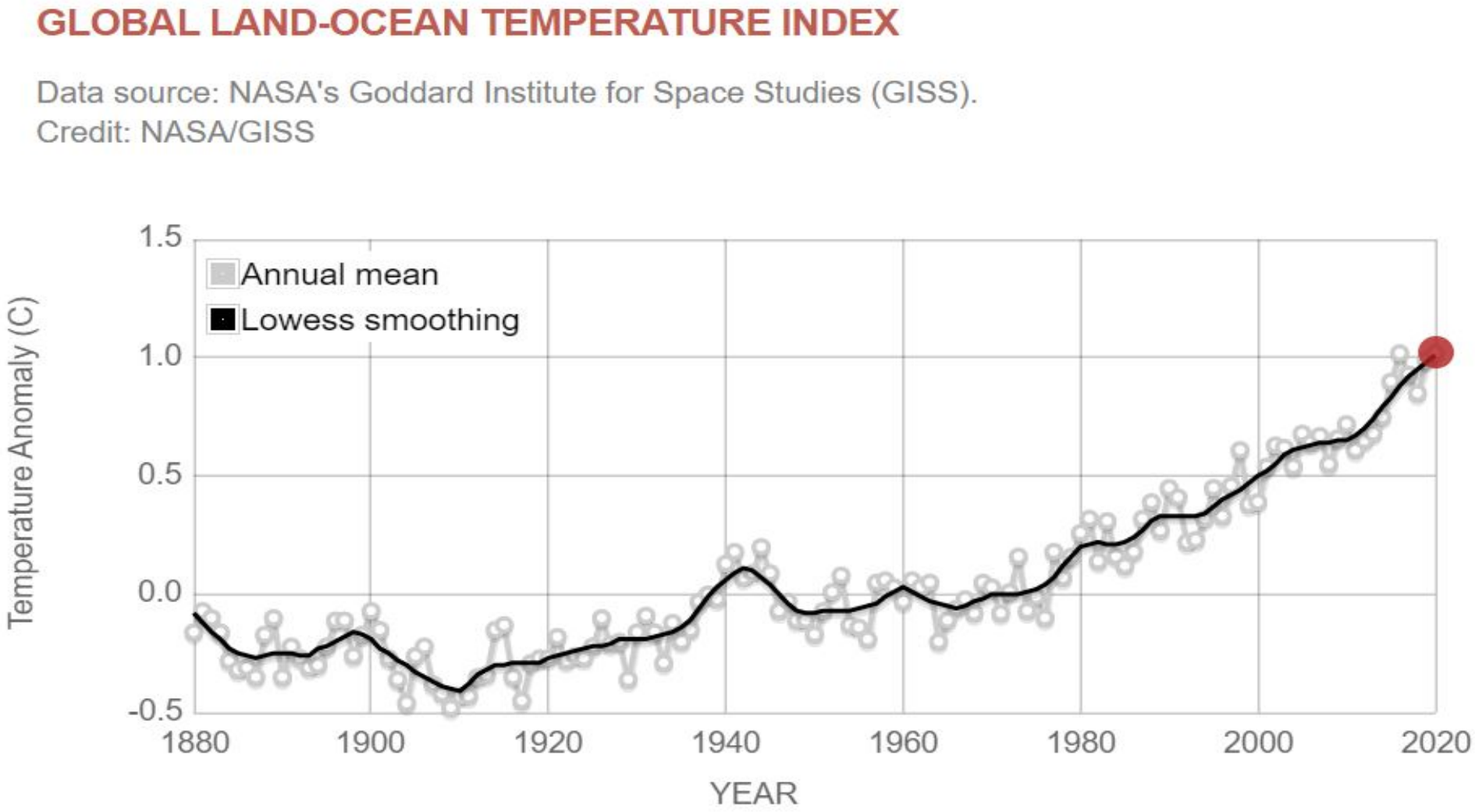
2021 Scientific Consensus

- Earth's atmosphere has warmed significantly since the 1950s (about 1.0^{O}C [1.8^{O}F]).
- Human activities (primarily GHG emissions and their accumulation in the atmosphere) are the primary cause for this global warming.
  - In August 2021, the U.N. Intergovernmental Panel on Climate Change (IPCC) stated that the evidence for human drivers is **"unequivocal."**
- A warmer Earth is changing climate patterns with adverse impacts to society at the California, U.S., and global scales.
- The world is struggling to reduce GHG emissions, notwithstanding national pledges to do so (i.e., Paris Climate Agreement)
  - These continuing high GHG emissions will cause more global warming for decades to come, resulting in increasingly frequent and severe adverse impacts.

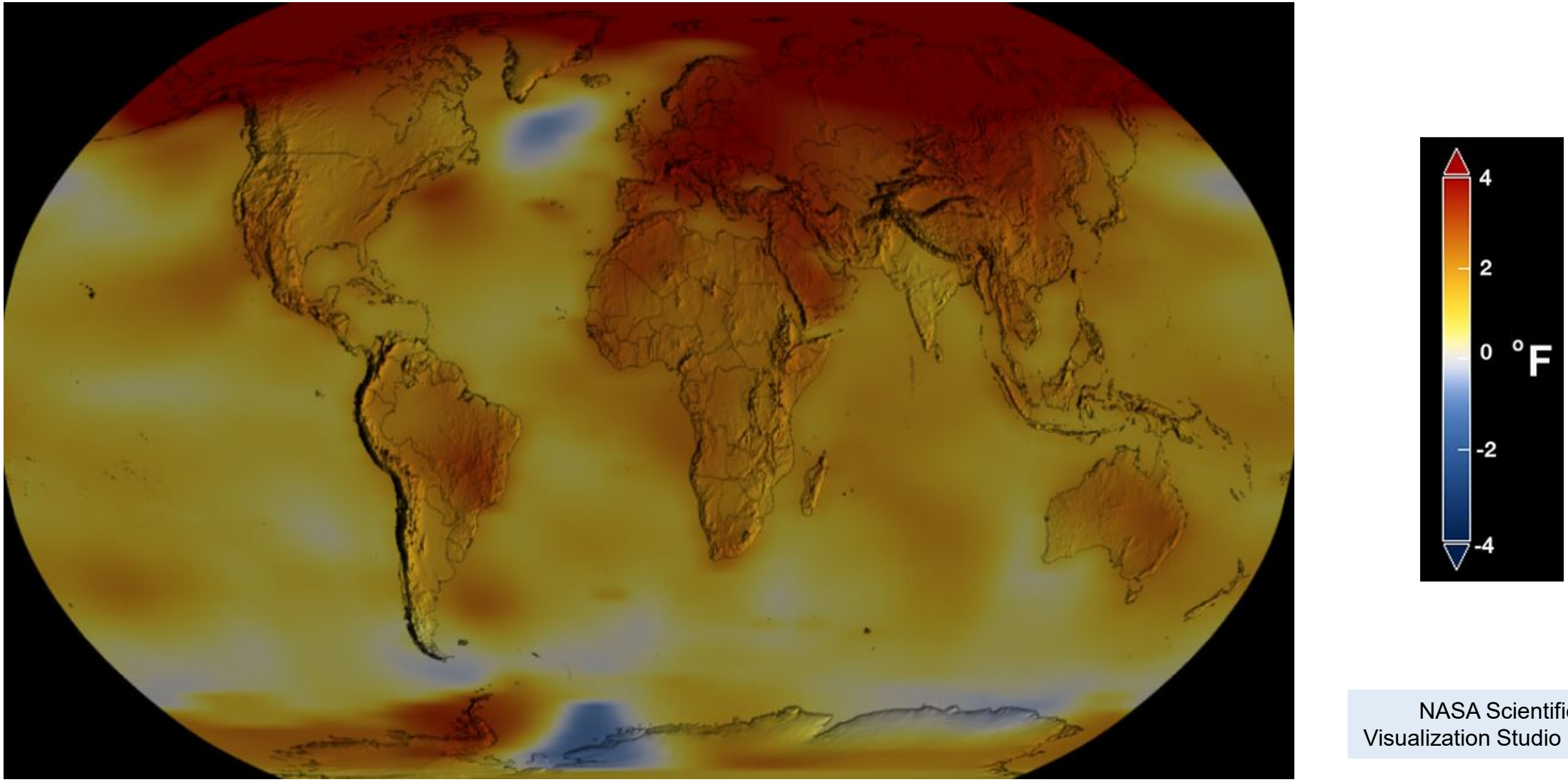
Atmospheric Carbon Dioxide Levels Continue to Rise (CO_2 increase > 2.0 ppm/year, on average)



Increasing Atmospheric Concentrations of GHGs are Increasing Absorption of the Earth's Infrared Radiation, Upsetting the Earth's Solar Energy Equilibrium and Increasing the Earth's Temperature



2016-2020 Average Surface Temperature Anomalies Compared to 30-Year Baseline Average (1951-1980)



NASA Scientific Visualization Studio (2020)

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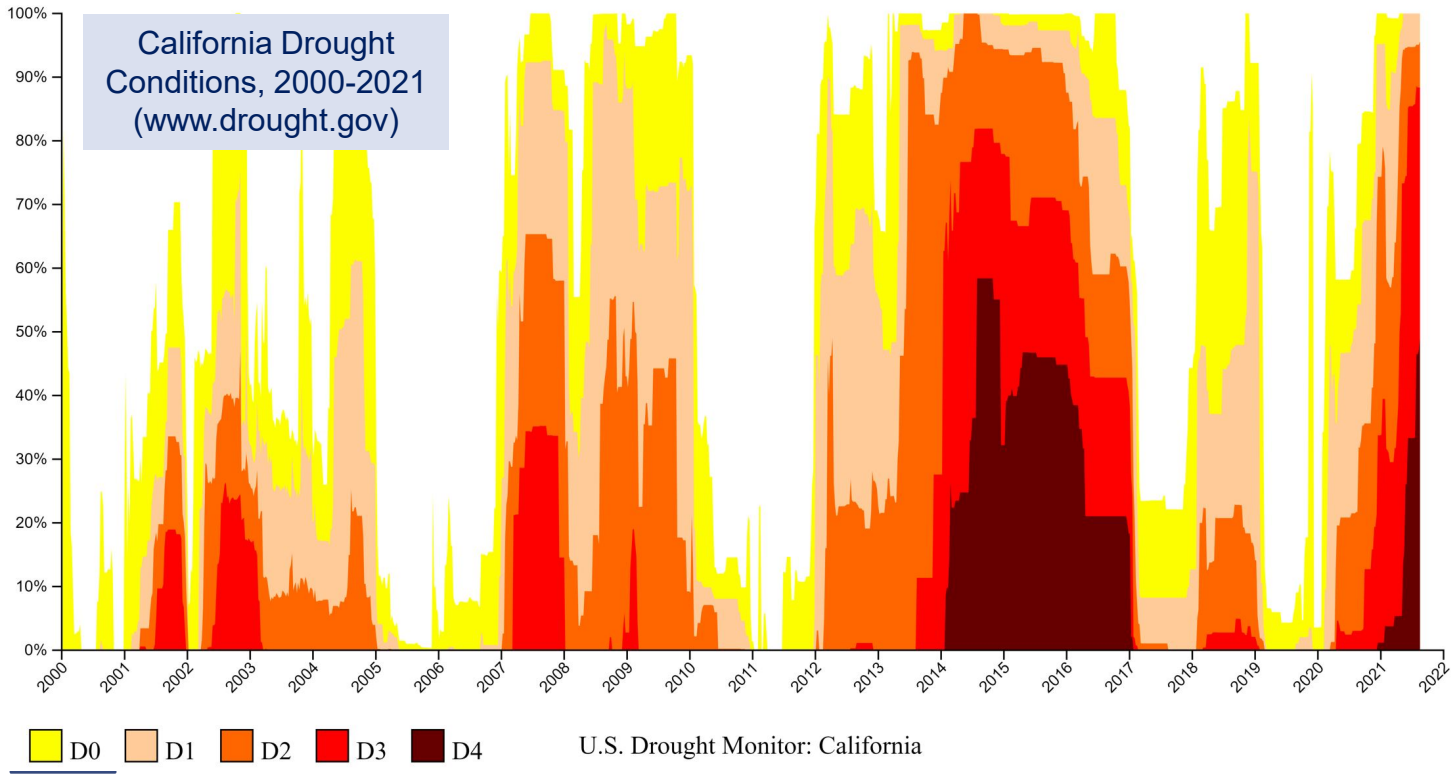
Fourth U.S. Climate Assessment (2017) – Manifestations of Climate Change in the U.S. That are Already Occurring

- Increasing temperatures
- **More severe droughts and heat waves**
- **Increased wildfire threats**
- **Less mountain snowpack**
- Changes in precipitation patterns
- More energetic storm systems
- Stronger and more intense hurricanes
- Groundwater aquifer depletion
- Groundwater quality degradation
- Surface-water quality degradation
- **Water supply disruptions**
- Arctic projected to become ice free in summer
- Antarctic losing ice mass at a rapid rate
- Glaciers continue to melt and shrink
- Increasing rate of sea level rise
- **Increasing coastal flooding**
- Increasing ocean acidification
- Loss of permafrost as methane sink
- Increasing coastal flooding and erosion
- Population disruptions
- Changes in agricultural patterns
- Food supply disruptions
- Ecological disruptions
- Impacts to all forms of infrastructure
- Impacts to communities and cities

Empirical Evidence – Increasing California Drought and Wildfires

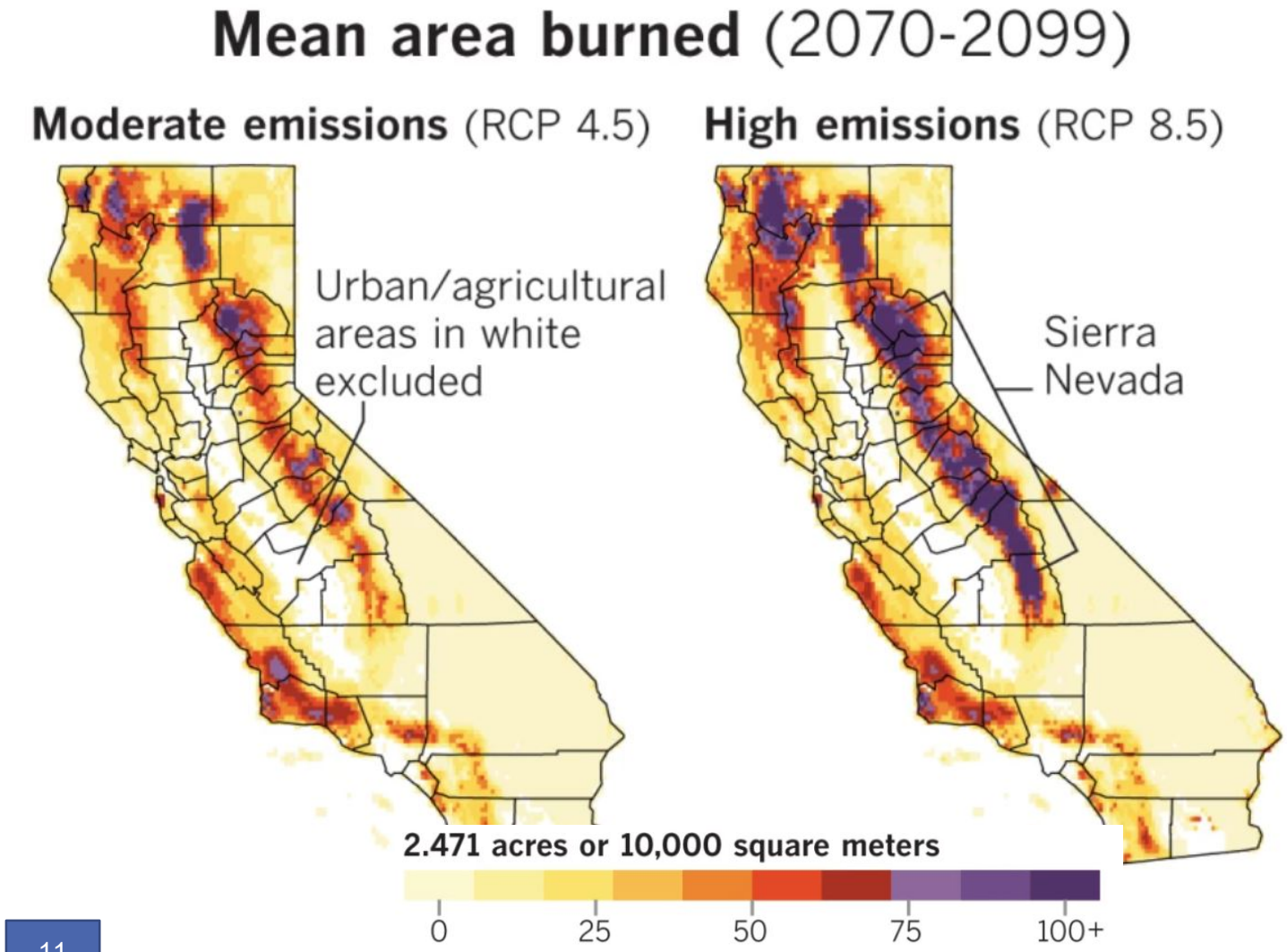
"In a year of superlatives, some statistics stand out for California's 2020 fire year: Four million acres burned, 112 million tons of greenhouse gases released….and 31 lives lost."

Cal Fire



August Fire Complex (2020) – Mendocino, Lake, Glenn, Tehama, and Trinity Counties - 1 million+ acres burned.

Scientific Projections – Increasing California Drought and Wildfires



Modeling conducted by UC Merced for the State of California predicts that as droughts become more prevalent, wildfires in the state's forested areas will become more frequent and larger in size, with annual average area burned in parts of the Sierra Nevada doubling by the late 21st century.

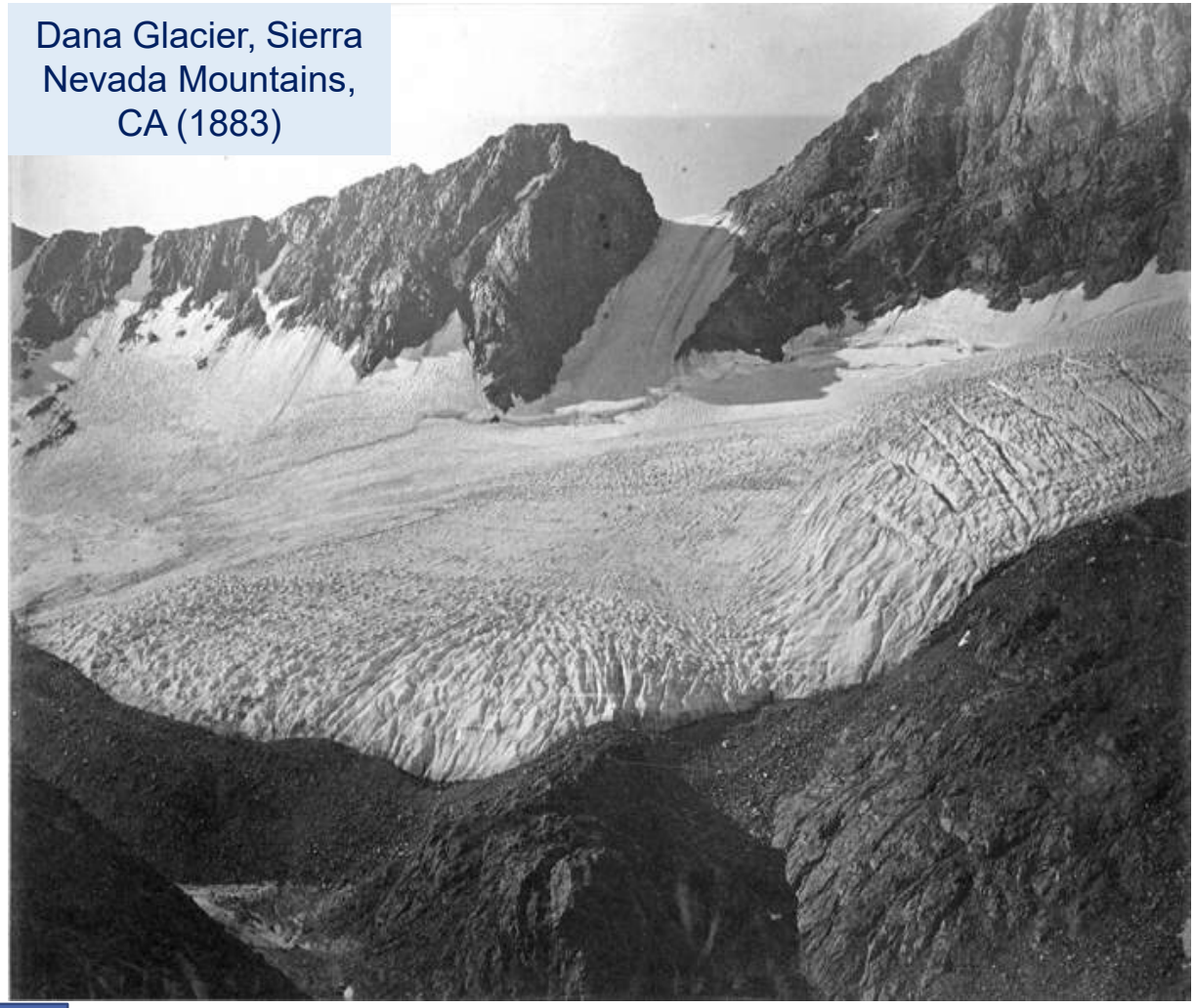
Westerling, U.C. Merced (2018)

Empirical Evidence – Increasing California Drought and Water Resource Depletion

Lake Oroville,
Lakehead, CA
July 22, 2021
(28% capacity,
200+ feet below
full pool)

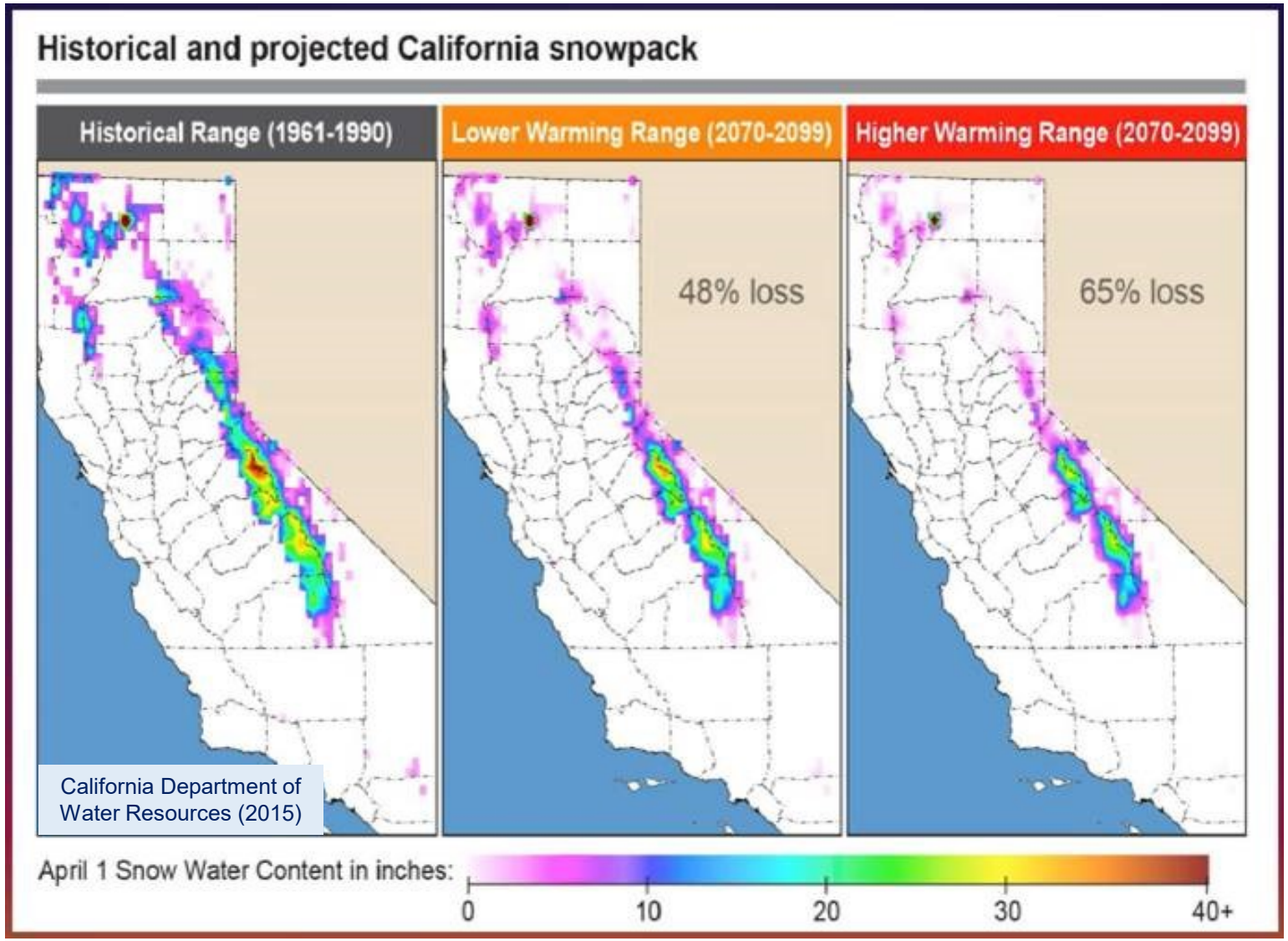
Empirical Evidence – Increasing Loss of California Snowpack and Glacial Ice and Water Resource Depletion

Dana Glacier, Sierra Nevada Mountains, CA (1883)



Dana Glacier, Sierra Nevada Mountains, CA (2015)

Scientific Projections - Changes in California Snowpack in 30 Years and in 2100

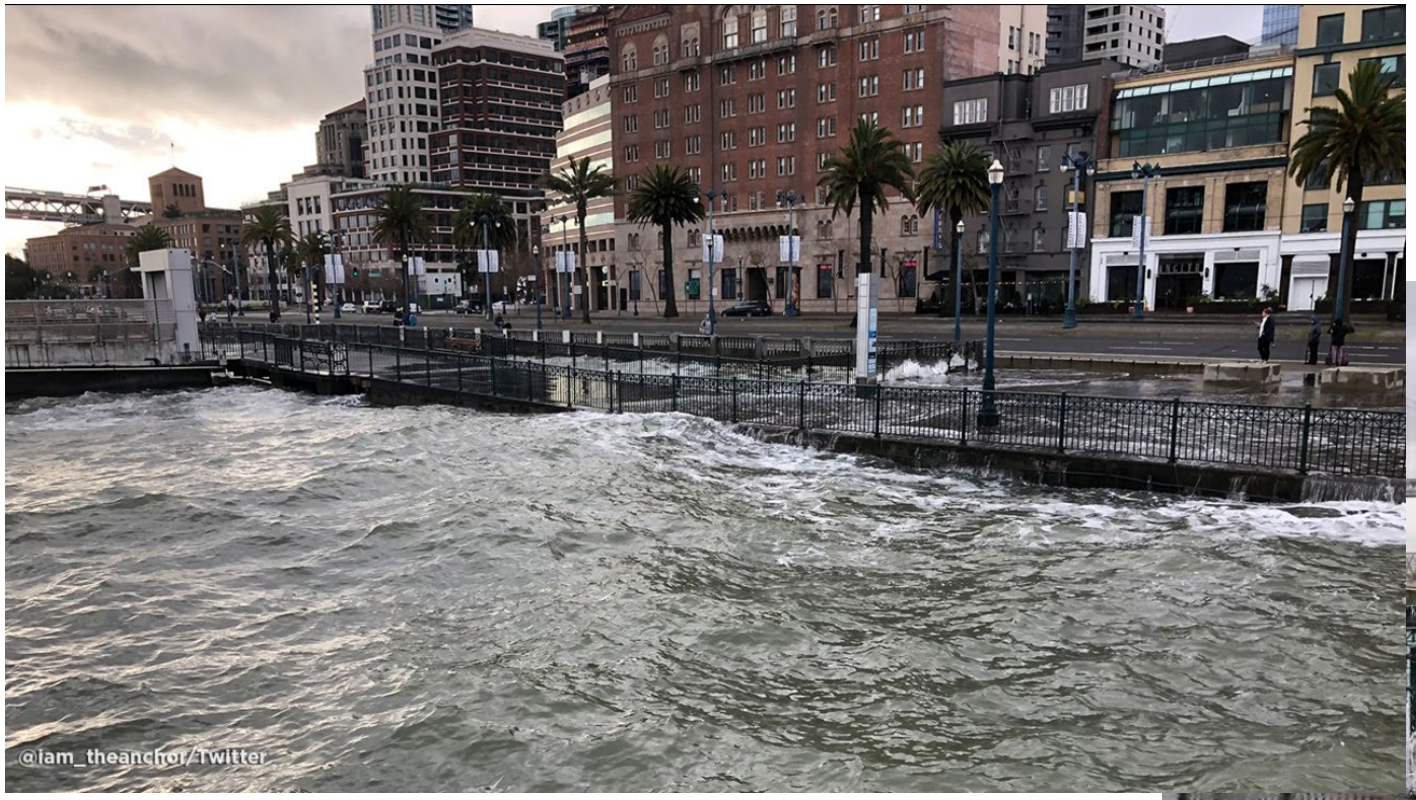


California Department of Water Resources (2015)

"By 2050, the average water supply from snowpack is expected to decline to 2/3 of historical levels. If emission reductions do not occur, water from snowpack could fall to less than 1/3 of historical levels by 2100."

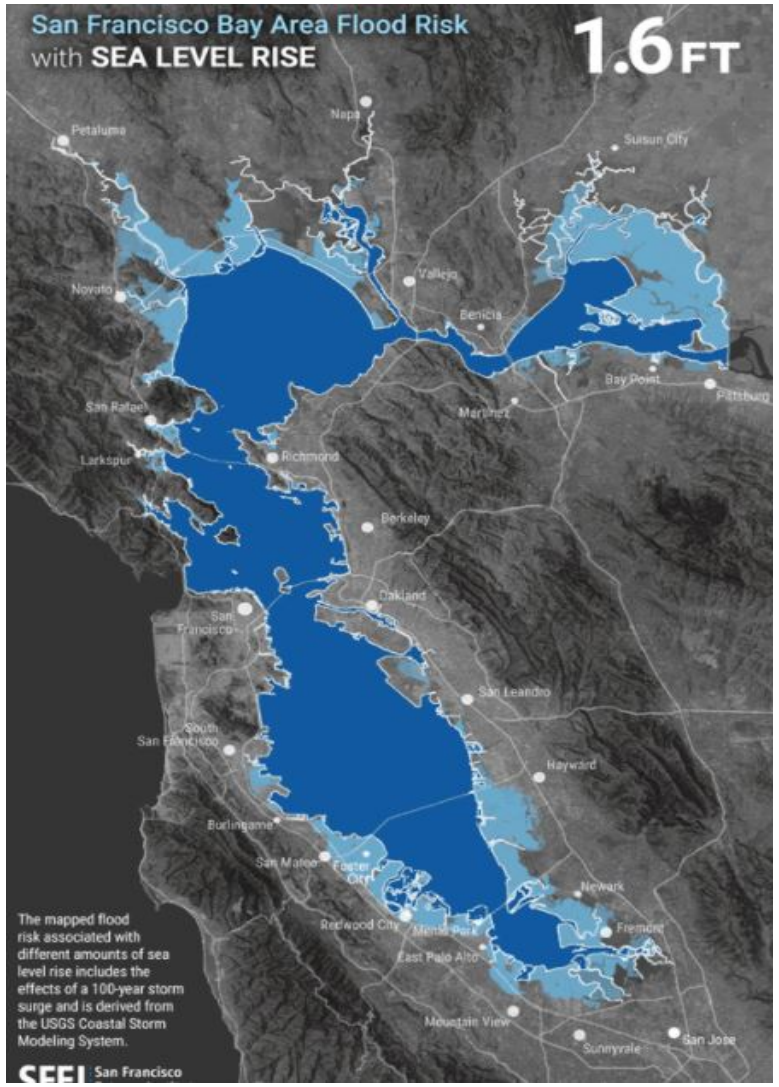
California's Changing Climate (2018)

Empirical Evidence – More Frequent Flooding at High Tides in San Francisco Due to Sea Level Rise

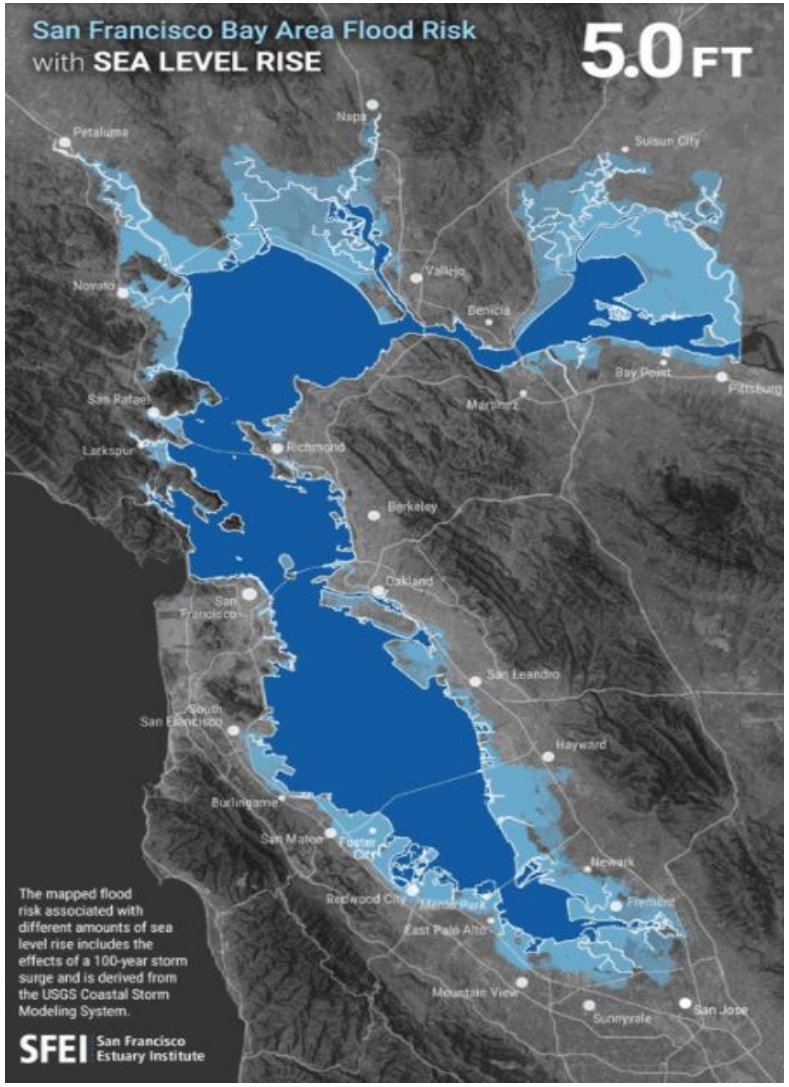


Scientific Projection - California Sea Level Rise Guidance (2018) indicates a 66% probability of 3 feet of SLR at San Francisco by 2100

Scientific Projections – Sea Level Rise and Increased Land Inundation and Storm Flooding Around San Francisco Bay



San Francisco Estuary Institute (2019)



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Approaches to Mitigating Climate Change and Global Warming (Reducing and/or Capturing GHG Emissions)

1. **Increasing use of renewable energy (solar, wind, hydropower, pumped-storage hydropower, nuclear) as a replacement for fossil fuels**
2. **Improving the nation's energy transmission and distribution grid,** developing microgrids, and improving and increasing the use of battery energy storage
3. **Reducing carbon emissions from current emission sources** (power, industrial, **transportation vehicles, and buildings**)
4. Developing zero and low carbon fuels (e.g., hydrogen, biofuels)
5. Increasing energy efficiency for all types of powered systems (reduce energy consumption and waste energy)
6. Improving land uses, forestry practices, and agricultural practices (reducing emissions and creating carbon sinks)
7. Increasing carbon capture and sequestration (CCS) and developing CO_2 mineralization technologies (carbon sinks)

Contributions of CEEs to Increasing Renewable Energy

Planning, Designing, Constructing, Improving, and Decommissioning

- Nuclear energy (19.7%[1])
- Wind energy (8.4%)
  - Onshore
  - Offshore
- Hydroelectric energy (7.3%)
  - Pumped-storage hydropower
- Solar energy (2.3%)
  - Photovoltaic (“solar panels”)
  - Solar thermal
- Biomass energy (1.4%)
- Geothermal energy (0.4%)
- Tidal energy (0%)

[1]Percent of U.S. 2020 electric energy generation (U.S. EIA, 2021)

Role of CEEs[2]

- Siting studies, planning, and risk analyses
- Environmental impact studies and permitting
- Water resource investigations
- Intake and receiving water studies
- Meteorological and oceanographic studies
- Flood and tsunami forecasting and analyses
- Geological, geophysical, and geotechnical investigations (onshore and offshore)
- Faulting, seismic hazard, site response, and soil-structure interaction studies
- Foundations and earthworks design
- Structural analysis and design
- Design of site civil infrastructure
- Design of stormwater and erosion control BMPs
- Environmental cleanup studies and design
- Environmental and construction monitoring
- Project and construction management

[2]Not all services apply to each category of renewable energy

Contributions of CEEs to Increasing Renewable Energy

377-MW Ivanpah Solar Thermal Plant, Mojave Desert, California

30-MW Block Island Wind Farm, Offshore Rhode Island

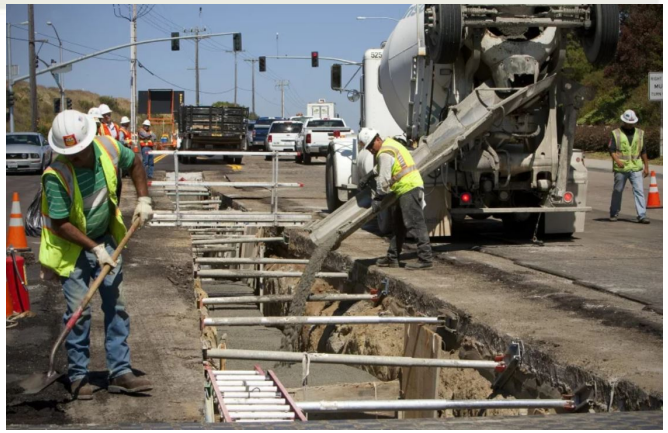
Denmark's Proposed North Sea and Baltic Sea Energy Islands

When first-phase construction is complete, these islands will concentrate up to 5 GW of energy generated by hundreds of wind turbines, store the energy in batteries for load leveling, and distribute the power through underwater cables to consumers in three countries.

The opportunities for CEEs to contribute to this type of renewable energy mega-project are enormous.

Improving the Energy Grid - Sunrise Powerlink Transmits Renewable Energy (Solar and Wind) from Imperial Valley to San Diego County

Project Description: The 117-mile long above/below ground transmission line delivers 1,000 MW of solar and wind energy to San Diego County

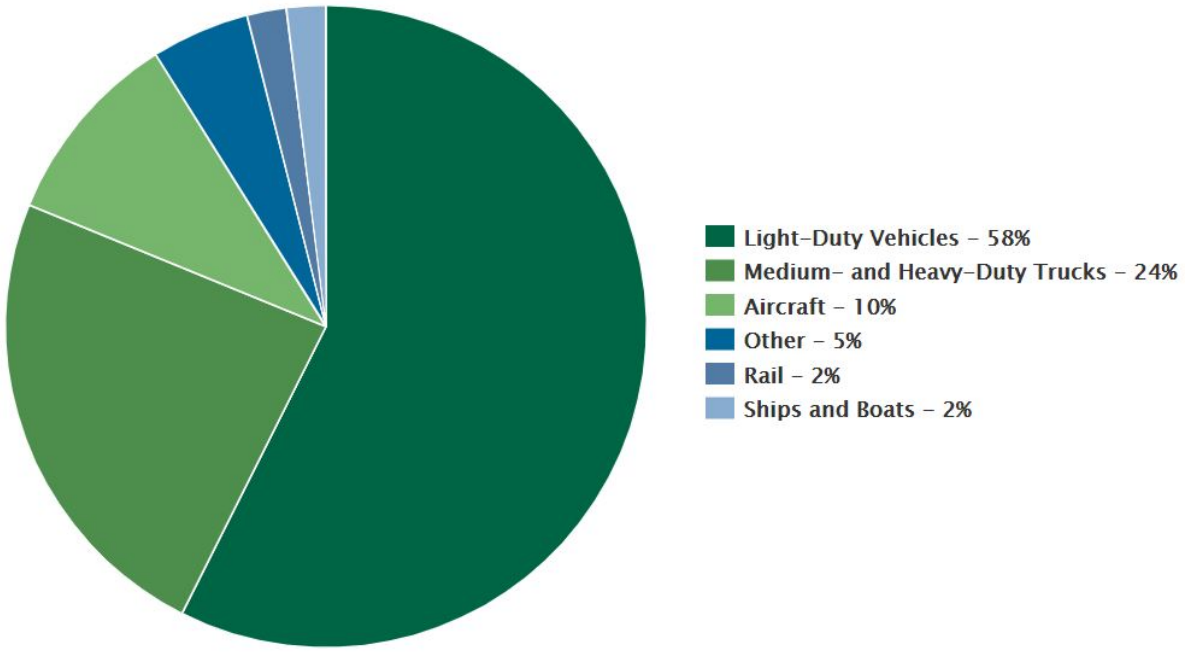


Role of CEEs

- Site selection, planning, and risk analyses
- Environmental impact studies and permitting
- **Corridor routing studies and planning for transmission lines**
- **Corridor natural hazard studies (faulting, landslides, karst, stream crossings)**
- Geological and geotechnical investigations
- Site grading and earthwork design (cuts, fills, retaining walls)
- **Design of transmission towers and foundations**
- **Design of underground transmission corridors (deep trenches, horizontal directional drilling (HDD))**
- Design of site civil infrastructure
- Design of stormwater and erosion control BMPs
- Environmental cleanup studies and design
- Environmental and construction monitoring
- Project and construction management

Contributions of CEEs to Mass Transit and Multi-modal Transportation Infrastructure Projects to Reduce Light-Vehicle GHG Emissions

2019 U.S. Transportation Sector GHG Emissions by Source



Light-duty vehicles are the largest contributors to GHG emissions. CEEs are not involved in mitigation measures involving increased fuel efficiency, non-carbon fuels (H_2), and electric vehicles, but…….

….CEEs are involved in

- Transportation ridership and route studies and planning
- **Traffic congestion modeling, routing, and debottlenecking**
- Transportation project impact studies (CEQA, EIS/EIR)
- **Mass transit alternatives analyses**, feasibility studies, and environmental impact assessments
- **Design of urban trolley and light rail systems**, including rights-of-way, horizontal and vertical alignments, bridges, tunnels, grade crossings, drainage and erosion control systems
- **Design of urban bicycle and pedestrian greenways and belt lines**
- Design of inter-urban passenger and freight heavy rail systems
- **Design of multi-modal transportation hubs**
- **Design of smart traffic control systems**
- **Design of green streets** (pedestrian, bicycle, car, mass transit)
- Engineering support for all these design categories, including structural, geotechnical, hydrology/hydraulics, environmental, and others
- Environmental and construction monitoring
- Project and construction management

Contributions of CEEs to Mass Transit and Multi-modal Transportation Infrastructure Projects to Reduce Light-Vehicle GHG Emissions

LA Metro Regional Light Rail Connector

California High Speed Rail

Contributions of CEEs to Energy Efficient (Green and Lean) Buildings

Representative Measures to Improve Building Energy Efficiency

- Locate in proximity to mass transit
- Consider building orientation to take advantage of sunlight
- Maximize use of utility renewable energy
- Integrate photovoltaics for energy self-sufficiency
- Consider geothermal energy and/or energy piles at appropriate locations
- Consider combined heat and power to increase energy efficiency
- Use energy efficient lighting and HVAC systems and smart power saving controls
- Use locally available and/or recycled construction materials
- Use renewable construction materials (e.g., wood) where possible
- Incorporate green roofs to reduce runoff and urban heat island effect
- Utilize roof-top rainwater harvesting systems, if allowed
- Evaluate grey-water and/or black-water collection, treatment, and on-property reuse
- Evaluate insulated glass on outer wall to decrease heat gain and loss from outside
- Recycle construction waste materials and site demolition materials

Role of CEEs

- Siting studies, permitting, and planning
- **Resource and energy efficient structural engineering and building envelope design** (e.g., small and light building footprints)
- **Resource and energy efficient building foundation design**
- Low-impact site civil design
- **Green roof design**
- **Rainwater harvesting design**
- **Specifying local, recycled, and/or renewable construction materials**
- **Requiring recycling of construction waste**
- Design of grey-water and/or black-water wastewater treatment systems
- Water efficient and ecologically beneficial landscaping
- Environmental and construction monitoring
- Project and construction management

Contributions of CEEs to Energy Efficient (Green and Lean) Buildings

UCLA Engineering VI
(rooftop solar, chilled beams, natural ventilation, solar chimneys, and light tubes)

Georgia Tech Engineered Biosystems Building
(rainwater harvesting, natural lighting, chilled beams, smart HVAC sensor system, and landscaping to create ecological habitat)

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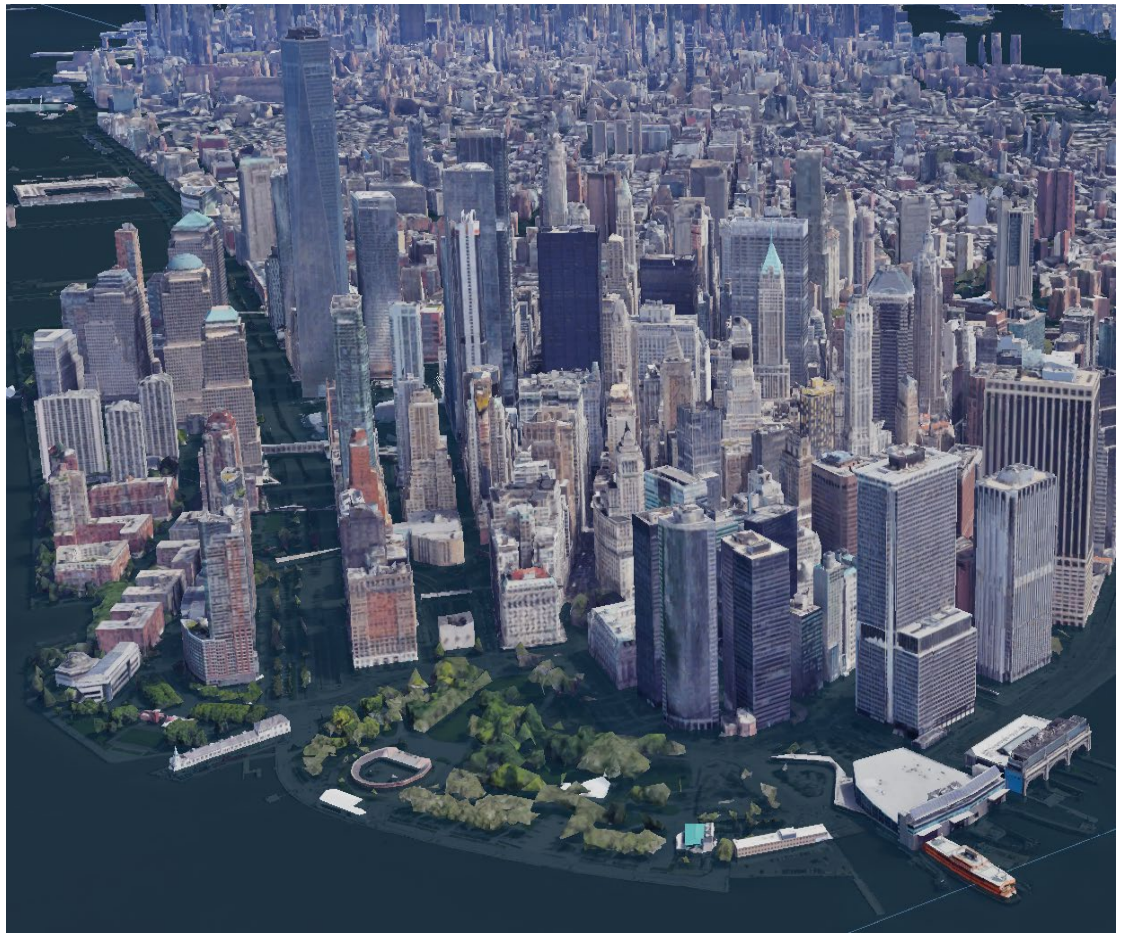
Partial List of Infrastructure and Environmental Sectors Requiring Climate Adaptation Measures

Infrastructure or Environmental Sector	Role for CEEs
Coastal communities and low-lying areas	✓
Coastal cities (buildings, basements, underground structures, subways, and utilities)	✓
Coastal transportation systems (roads, tunnels, bridges, airports, mass transit)	✓
Ports and harbors; inter-coastal and inland waterways	✓
Rivers and riverine infrastructure	✓
Communities everywhere at increased risk of flooding due to extreme weather	✓
Surface-water and groundwater resources (both quantity and quality)	✓
Water supply infrastructure (reservoirs, storage tanks, canals, pipelines)	✓

Infrastructure or Environmental Sector	Role for CEEs
Electric power infrastructure and the electrical transmission and distribution grid	✓
Industrial, military, governmental infrastructure (both coastal and inland)	✓
Barrier islands, beaches, dunes, salt marshes, wetlands, estuaries, critical wildlife habitat (loss of and damage to)	✓
Terrestrial, freshwater, marine, and avian wildlife	✓
Contaminated land (EPA Superfund sites) in floodplains and coastal areas	✓
Land aridification and agriculture	✓
Natural hazards (wildfires, hurricanes, tornadoes, floods, landslides and debris flows)	✓
Air quality (dust and particulates, wildfire impacts)	✓

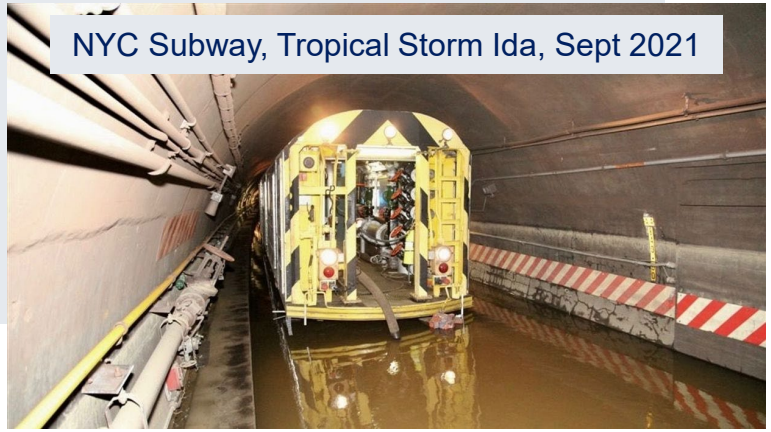
Sea Level Rise Adaptation - Coastal Cities



Inundation of Lower Manhattan for 2°C Warming Scenario

CEEs have a major role to play in engineering adaptations for city infrastructure prone to increasing storm and tide inundation:

- **Storm surge and inundation modeling and analyses**
- Floodplain mapping
- **Risk, recurrence, and vulnerability studies**
- **Event forecasting and real time monitoring**
- **Studies, engineering, and design for:**
  - **Sea walls, storm-surge barriers, tide gates, and pump stations**
  - Protecting or relocating roads, subways, and utilities
  - Improving power reliability and increasing backup power sources
  - **Protecting or relocating critical infrastructure**
  - Waterproofing buildings
  - **Protecting infrastructure from saltwater corrosion**
  - Improving and expanding stormwater retention systems



NYC Subway, Tropical Storm Ida, Sept 2021

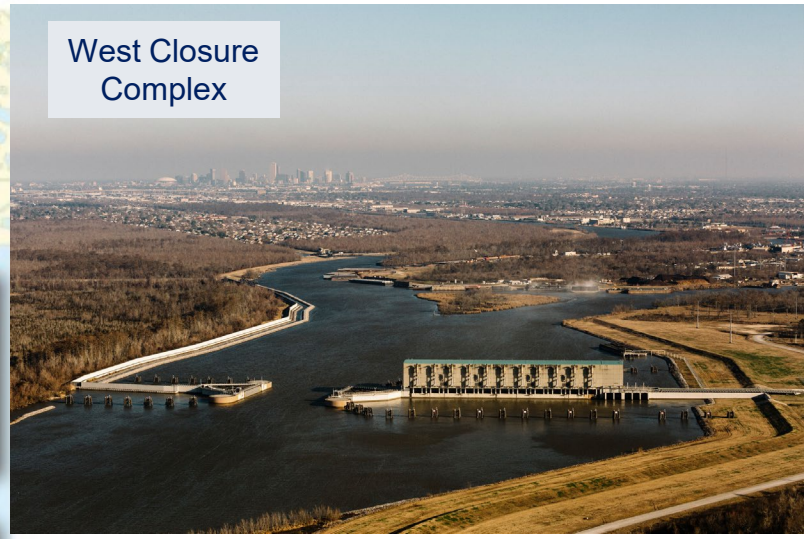
Sea Level Rise Adaptation - San Francisco International Airport Shoreline Protection Program

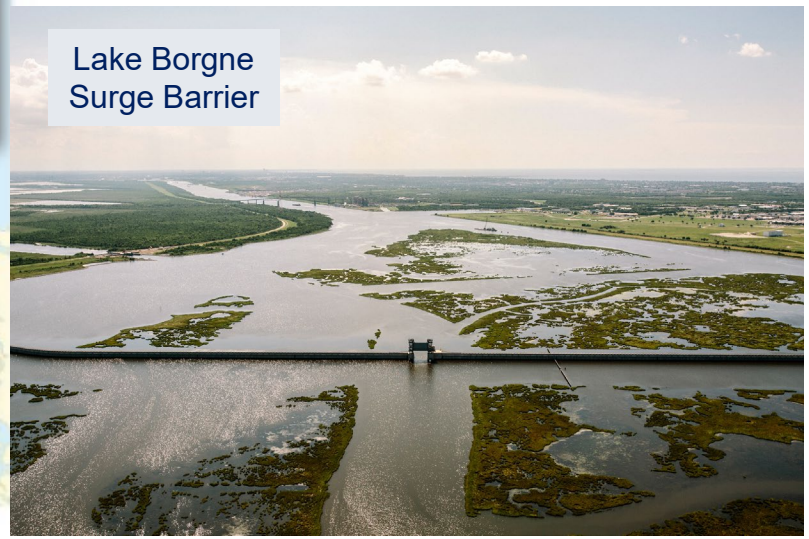
Source: San Francisco International Airport

BAY AREA NEWS GROUP

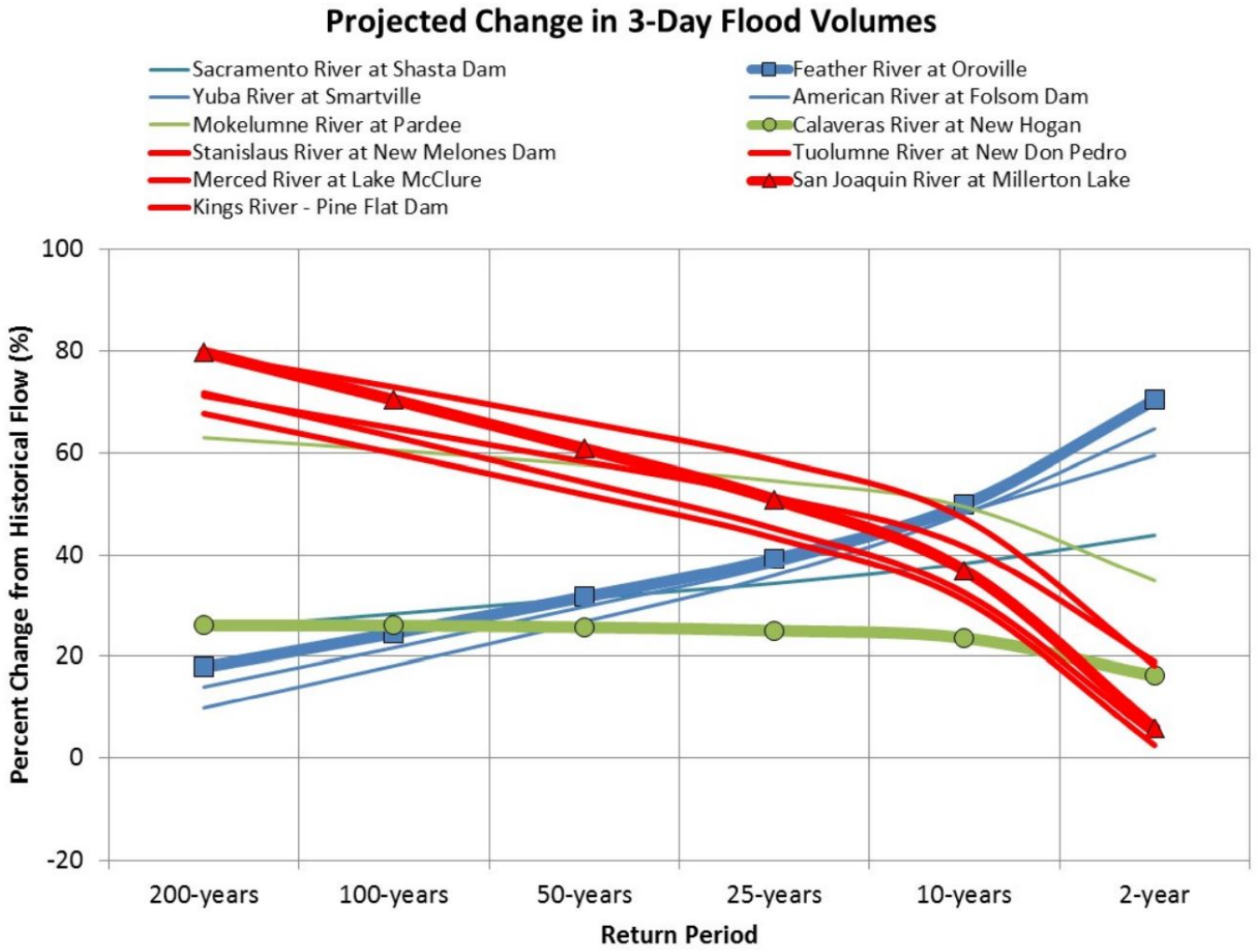
Project will involve providing 5-feet of additional protection against sea level rise, extreme tides, and storm waves around the entire 8-mile airport perimeter. Waterfront will use a continuous system of concrete-capped steel sheet piles and king piles, with riprap protection to break up waves. All this will be designed by CEEs.

Sea Level Rise Adaptation – Greater New Orleans Flood Protection and Risk Reduction System ($15 Billion)





River/Reservoir Adaptation – Increasing Flood Hydrographs for Sacramento-San Joaquin Valley Rivers (by mid-century)

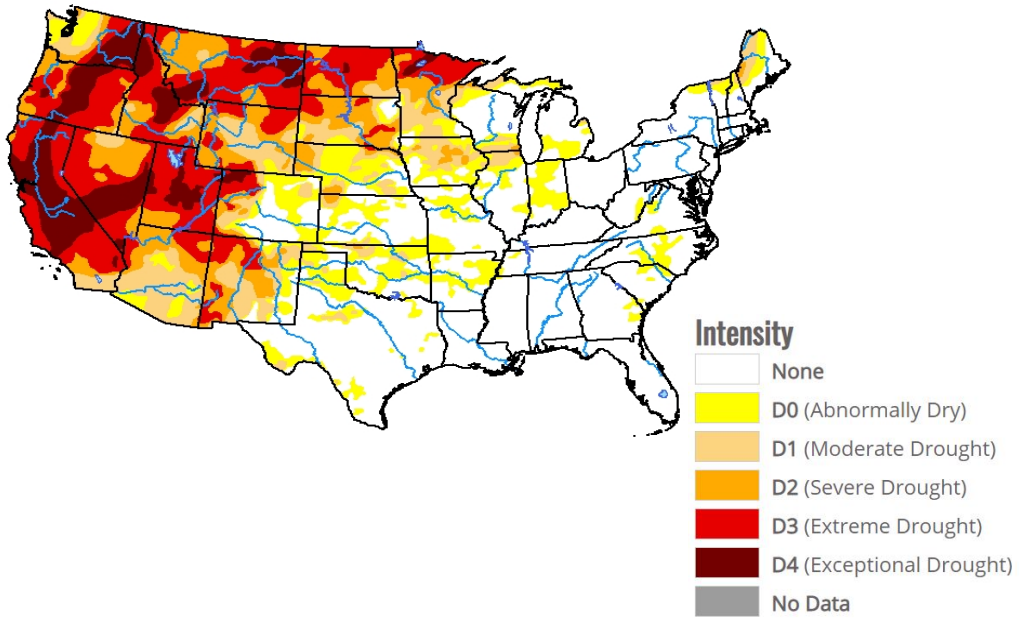


California DWR Climate Action Plan Phase 3: Vulnerability Assessment (2019)

CEEs have a major role to play in adapting California DWR and other water agency (LADWP, LA MWD, EBMUD) infrastructure:

- Watershed and hydrologic studies
- **Flow and flood forecasting**
- Floodplain delineations
- River erosion and sedimentation evaluations
- **Evaluations and retrofits of bridges and other riverine infrastructure**
- Reservoir operational optimization
- **Dam and spillway hydraulic and structural capacity studies**
- **Dam and spillway improvements**
- **Water quality studies**
- **New reservoir siting and design**
- Ecological and environmental studies and restoration
- Environmental and construction monitoring
- Project and construction management

Water Supply Adaptation – Responding to Diminishing and Less Reliable Water Supplies

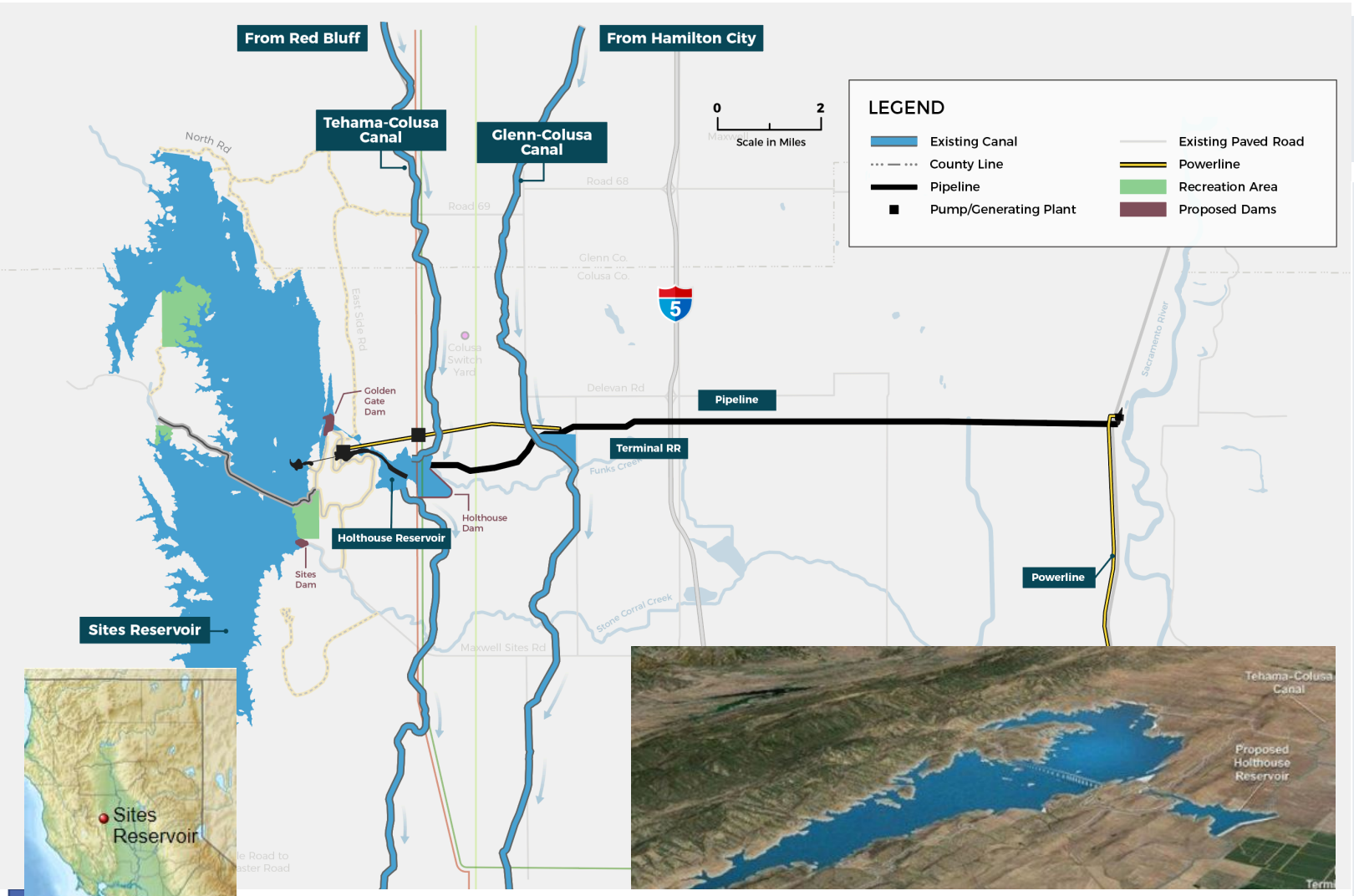


U.S. Drought Monitor, Sept 16, 2021

CEEs have a major role to play in adapting to diminishing and less reliable water supplies. Needed projects include water conservation, water reuse, water storage and conveyance, and saltwater desalination:

- Watershed and hydrologic evaluations
- **Stormwater capture and groundwater infiltration**
- **Seawater desalination plants**
- **Rainwater harvesting systems**
- Grey-water and black-water recycling systems
- Reservoir management and operational optimization
- **New reservoirs and water conveyance systems**
- Water quality studies
- **Water conservation programs**
- Ecological and environmental restoration
- Environmental and construction monitoring
- Project and construction management

Water Supply Adaptation - Proposed Sites Reservoir, Colusa County, CA



This off-stream reservoir will be more than 10-miles long, more than 250-ft deep, with 1.5 million acre-feet of storage.

Role of CEEs

- **Siting studies, planning, risk analyses**
- Environmental impact studies and permitting
- Water resource investigations
- **Reservoir modeling (hydrodynamic and thermal)**
- Hydrology and hydraulics studies
- Geological, geophysical, and geotechnical investigations
- **Faulting, seismic hazard, site response, and soil-structure interaction studies**
- **Design of new dams, spillways, intakes, gates, tunnels, pipelines, and pump stations structures**
- Design of site civil infrastructure
- Environmental cleanup studies and design
- Environmental and construction monitoring
- Project and construction management

Water Supply Adaptation - Trampas Canyon Reservoir and Dam, San Juan Capistrano, CA

This project created a 5,000-acre-feet recycled water reservoir impounded by a 216-foot-high embankment dam. The reservoir will store recycled water in the winter months (when it is not needed) for irrigation uses in the dry summer months, saving potable water for human use.

There are numerous opportunities for CEEs to contribute to a project like this, from permitting and environmental studies, to design of the wastewater recycling facility, dam and reservoir, pump station, and inlet and outlet water conveyance pipelines.

Water Supply Adaptation - Carlsbad California Desalination Plant

The Carlsbad Desalination Plant is the largest and most energy-efficient seawater desalination plant in the nation. Each day, the plant delivers nearly 50 million gallons of desalinated water to San Diego County – enough to serve approximately 400,000 people. This project lessens Southern California's dependence on imported Colorado River water.

There are numerous opportunities for CEEs to contribute to a project like this, from permitting and environmental studies, to design of the ocean intake pipeline, plant structures, reverse osmosis water treatment system, outlet water pump station, and water conveyance pipelines.

Project partners: Poseidon Water and San Diego County Water Authority

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American Society of Civil Engineers (ASCE) Code of Ethics

- "Members of ASCE conduct themselves with integrity and professionalism, and above all else **protect and advance the health, safety, and welfare of the public** through the practice of Civil Engineering."
- "Engineers govern their professional careers on the following fundamental principles:
  - **create safe, resilient, and sustainable infrastructure**
  - treat all persons with respect, dignity, and fairness in a manner that fosters equitable participation without regard to personal identity
  - consider the current and anticipated needs of society
  - **utilize their knowledge and skills to enhance the quality of life for humanity**

ASCE (2020)

Professional and Leadership Responsibilities of CEEs in Abating the Climate Change Crisis (My Humble Opinion)

- Communicate to the public the science that "unequivocally" (IPCC) demonstrates human-induced GHG emissions are driving global warming and the myriad manifestations of that warming – build public support for action
- Advocate for and contribute to projects and actions to mitigate global warming and help society adapt to the effects of a warmer and more extreme climate
- Embrace and implement the principles of low-carbon, resilient, and sustainable design in your professional activities (e.g., USGBC LEED)

As we've seen today, climate change mitigation and adaptation will spur countless projects involving CEEs, and we have a professional and leadership responsibility to contribute all we can

With one of the best CEE educations in the world (UCLA) you can make a real difference for good

Thank You

I want to extend my thanks to Leslie and Dennis Drag who through their generosity made this lecture possible and to the UCLA CEE Department for inviting me to be here today.